LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA16 | Ladbroke and Southam

Flood risk assessment (WR-003-016)

Water resources

November 2013

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Department for Transport

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Appendix WR-003-016

Environmental topic:	Water resources and flood risk	WR
Appendix name:	Flood risk assessment	003
Community forum area:	Ladbroke to Southam	016

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise of four parts. The first of these is a route-wide appendix (Appendix WR-001-000).

1.1.2 Three specific appendices for each community forum area (CFA) are also provided. For the Ladbroke to Southam area (CFA16) these are:

1.1.3 a water resources assessment (Appendix WR-002-016);

- a flood risk assessment (FRA) i.e. this appendix; and
- a river modelling report (Appendix WR-004-009).

1.1.4 Maps referred to throughout the water resources and FRA appendices are contained in the Volume 5 Water resources map book.

1.2 Scope of this assessment

1.2.1 This FRA considers the assessment of flood risk in this study area, which is defined as the area within 1km of the route within CFA16. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 This FRA presents baseline (current day) flood risk and post-construction flood risk as a result of the Proposed Scheme and has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of the document is on the change in risk status to local receptors, particularly existing infrastructure.

1.2.3 A risk-based methodology has been adopted through the application of the source-pathway-receptor model. This model has been used to identify the cause of 'sources' of flooding to and from a development. The identification is based on a review of local conditions and consideration of the effects of climate change.

1.2.4 In order for there to be a flood risk, all the elements of the model (a flood source, a pathway and a receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model, for example by removing the pathway or receptor.

1.2.5 Receptors may include people and their properties, business and infrastructure, and the built and natural environment within the range of the flood source which are connected to the source of flooding by a pathway.

[1] Department for Communities and Local Government (2012), *National Planning Policy Framework.*

1.2.6 This FRA has been completed to inform the Environmental Statement (ES) for the works, which will be a key part of the HS2 hybrid Bill submission required for the Proposed Scheme. The hybrid Bill is necessary for powers to build the railway, powers to buy land and for planning consent.

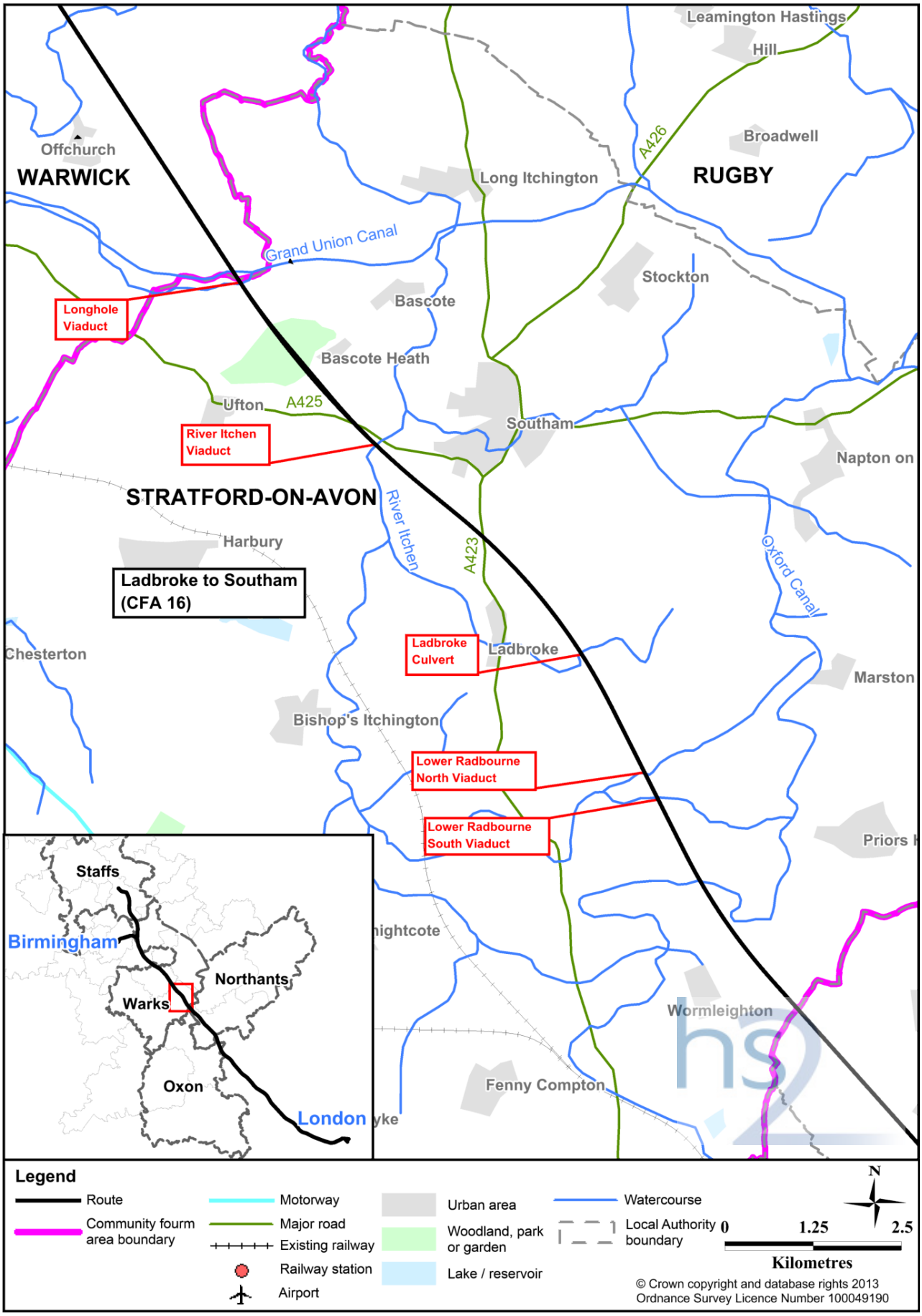
1.2.7 The Proposed Scheme will cross numerous surface water features within this study area including the River Itchen, four of its tributaries, a tributary of the River Leam and the Oxford and Grand Union Canals.

1.3 Location

1.3.1 In this FRA the study area covers a 13.1km section of the Proposed Scheme in the Stratford-on-Avon district, where it passes to the west of Southam. It extends from Wormleighton in the south to the Grand Union Canal at the boundary with Warwick District in the north. The area includes land within the parishes of Stoneton, Wormleighton, Priors Hardwick, Radbourn, Hodnells and Wills Pastures, Ladbroke, Southam, Ufton and Long Ichington.

1.3.2 A location plan of the Proposed Scheme within this study area is shown on Figure 1.

Figure 1: Location Plan



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewers) in the short or medium term. Stored rainfall, either naturally in aquifers (groundwater) and natural lakes, or artificially impounded in reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded.

2.1.2 A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea. However given the inland location of this study area, this final source of flooding does not pose a risk.

2.1.3 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.4 In general, receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the route. However, any receptors beyond this where a significant impact was expected were considered in this assessment. The Proposed Scheme includes all associated temporary and permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is required as part of the design to prevent an increase in flood risk in line with recommendations in the NPPF.

2.1.5 The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.6 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme will ensure that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

2.1.7 The FRA defines the baseline flood risk and vulnerability of receptors. This is used to define the value, importance and significance of effects which is provided within the ES.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance*.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water/ overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	
Groundwater[5]		Very low-low	Moderate	High-very high	
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	
Artificial sources[7]	Outside of inundation mapping / no pathway exists	Within inundation mapping / pathway exists			

2.3 National planning policy framework

2.3.1 This assessment of flood risk makes use of the NPPF[1] which is the Government's planning policy in relation to development and flood risk. It is set out within the NPPF that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere. The NPPF requires that proposed development located within Flood Zones 2 and 3 is assessed in relation to flood risk. This includes both flood risk to the development and any increases in flood risk elsewhere as a result of the development, with an allowance for climate change.

2.3.2 Methods used to ensure that development is at the lowest possible risk and that the development is safe without causing an increased risk elsewhere includes the application of the Sequential and Exception Tests. However, the Sequential Test has been considered as part of the overview FRA for the Proposed Scheme presented in Volume 3 of the ES and hence has not been repeated in this FRA.

[3] River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.
[4] Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).
[5] Groundwater flood risk taken from local flood risk assessment reports.
[6] Identified using the Severn Trent Water's assets network.
[7] Risk from reservoir flooding identified using the Environment Agency reservoir inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

Flood zone classification

2.3.3 The NPPF splits the Environment Agency's Flood Map into three separate Flood Zones. These Flood Zones should be used in determining the appropriateness of proposed development uses and they represent flooding without flood defences in place.

2.3.4 The Flood Zones are defined as:

- Flood Zone 1 – areas with a 'low probability' of flooding and where the annual probability of flooding is lower than 0.1% for either river or sea flooding. The NPPF imposes no constraints upon the type of development within Flood Zone 1;
- Flood Zone 2 – areas with a 'medium probability' of flooding and where the annual probability of flooding is between 0.1 and 1.0% for river flooding or between 0.5 and 0.1% for sea flooding. The NPPF recommends that Flood Zone 2 is suitable for most types of development with the exception of 'highly vulnerable' land uses; and
- Flood Zone 3 – areas with a 'high probability' of flooding and where the annual probability of flooding is 1.0% or greater for river flooding or 0.5% or greater for sea flooding. The NPPF recommends that appropriate development is based upon a further classification of Flood Zone 3: 3a high probability and 3b functional floodplain (where water has to flow or be stored in times of flood).

2.4 Local flooding planning policy documents

2.4.1 The local policies for this study area with implication in relation to flood risk are:

- Stratford-on-Avon District Local Plan Review 1996-2011[8] – PR7 Flood Defence. Policy PR7 requires that an assessment of flood risk must be completed for areas at risk from flooding, which must be appropriate to the scale and nature of the development. The assessment must indicate that the development is at an appropriate level of risk and will not exacerbate existing flood risk problems or give rise to new ones; and
- Stratford-on-Avon District Local Plan Review 1996-2011 – DEV 7 Drainage. Policy DEV 7 requires that sustainable drainage systems are incorporated into development for the disposal of surface water.

2.4.2 The Stratford-on-Avon Strategic Flood Risk Assessment (SFRA)[9] and the Warwickshire Preliminary Flood Risk Assessment (PFRA)[10] aid the councils in preparing sustainable policies for the long-term management of flood risk and improving existing emergency planning procedures. The SFRA is used as an evidence base to promote the location of future development primarily in low flood risk areas. This SFRA has been used to inform this FRA.

[8] Stratford-on-Avon District Council (2011), *Stratford-on-Avon District Local Plan Review*.
[9] Stratford-on-Avon District Council (2008), *Strategic Flood Risk Assessment*.
[10] Warwickshire County Council (2011), *Warwickshire Preliminary Flood Risk Assessment*. Completed by Royal Haskoning on behalf of Warwickshire County Council.

2.5 Historical sources of flooding

2.5.1 The historical flooding which has occurred either at the location of the route or in close proximity, have been determined as part of this FRA. These areas of historical flooding have been identified because places which have flooded in the past may be more susceptible to flooding in the future. Two sources of data relating to historical flooding have been used: local authority information (the relevant SFRA and PFRA) and extents of historical sources of river flooding as provided by the Environment Agency.

2.6 Flood risk approach

River flooding approach

Crossing locations

2.6.1 To determine the river flood risk at locations where the route will cross watercourses and to identify any changes in flood risk as a result of the Proposed Scheme, either existing hydraulic models have been used where available or new hydraulic models have been constructed. Where new models were required flows have been determined in line with current flood estimation guidelines[11].

Flow estimation

2.6.2 Existing hydraulic modelling was available to assess flood risk at the River Itchen viaduct (Volume 5: Map Book, Map WR-01-026, B6) through the use of the River Leam Hazard Mapping Study[12], and hence flows at this location were taken from the existing River Leam model.

2.6.3 The other watercourses which will be crossed by the route within this study area have no known detailed modelling available. Where Flood Zones are associated with these watercourses, the outlines have been determined through the use of broadscale topographic data, which are considered to be a rough guide when determining areas at risk of flooding and hence have not be used for the design of engineering works. There are other watercourses which have no associated Flood Zones. Flows for these watercourses, at the location of the proposed crossing, have been determined for the 1 in 20 (5%), 1 in 100 (1%), 1 in 100 (1%) with a 20% allowance for climate change and 1 in 1000 (0.1%) annual probability events.

2.6.4 A quick estimation of flow was produced at the crossing locations using the Revitalised Flood Hydrograph model (ReFH) where the contributing catchments were represented within the Flood Estimation Handbook (FEH) CD-ROM[13]. A FEH calculation record for the estimation of flow using ReFH is provided in the river modelling report (Volume 5: WR-004-009).

Modelling approach

2.6.5 The River Leam Hazard Mapping Study model included flow for the River Itchen but the hydraulic model extent did not cover the River Itchen viaduct (Volume 5: Map WR-01-026, B6) and hence a new model was built at this location. At crossings where

[11] Environment Agency (2012), *Flood estimation guidelines*.
[12] Environment Agency (2010), *River Leam Hazard Mapping*. Completed by JBA on behalf of the Environment Agency.
[13] Centre for Ecology and Hydrology (2009) *FEH CD-ROM Version 3*, ©NERC (CEH).

suitable models were not available new hydraulic models were built utilising the new high resolution Light Detection and Ranging (LiDAR) data collected for the purposes of the Proposed Scheme. Further detail in relation to the hydraulic modelling is included in the river modelling report (Volume 5: WR-004-009).

2.6.6 There are several road embankments and raised infrastructures across the watercourses which will potentially provide constriction to flows. The model Digital Terrain Model (DTM) had to be modified to allow for flows through culverts underneath these embankments. In the absence of any survey data of these road embankment culverts, a channel opening of 5m was incorporated at each of these embankments.

2.6.7 The inflow boundaries were mostly applied as steady state flows with unsteady flows applied for certain watercourses. For watercourses with floodplain attenuation such as ponds and lakes or significant obstructions to flow (e.g. due to embankments), the inflows were modelled using unsteady hydrographs. These models were run at longer durations covering the period of the hydrograph and attenuation. The resulting baseline (current) models were run for the 1 in 100 (1%) annual probability with an allowance climate change and 1 in 1000 (0.1%) events over a range of durations depending upon the flow conditions.

2.6.8 The Proposed Scheme models included either viaducts or culverts depending on the scheme design. The railway embankments were represented by modifying the model DTM at those locations. The 1 in 100 (1%) annual probability with an allowance for climate change peak flood levels upstream of the crossings were compared to the baseline (current) levels to assess the change in flood risk. The 1 in 1000 (0.1%) annual probability peak levels were extracted to inform the vertical alignment of the track.

River flood risk elsewhere along the route

2.6.9 In addition to watercourse crossings, there are sections of the route which are located in areas potentially at risk of river flooding. These have been identified through the use of the Environment Agency Flood Zone mapping. This mapping has been used in preference to SFRA mapping as it is considered more up to date and hence likely to best reflect areas at risk. River flood risk to these sections of the route needs to be determined both to prevent an unacceptable risk to the Proposed Scheme and to prevent it increasing flood risk as result of a reduction in floodplain storage.

Summary of river flooding approach

2.6.10 Due to the number of river crossings, varying complexities, and the amount of data and information available for each, at some locations the modelling approach is highly specific. These locations have been reported as such and further information is included in the river modelling report (Volume 5: WR-004-009).

Surface water flood risk

2.6.11 The baseline (current) assessment of surface water flood risk was completed using the Flood Maps for Surface Water (FMfSW). The maps utilised for this assessment are listed as:

- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.1m deep;

- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.3m deep;
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.1m deep; and
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.3m deep.

2.6.12 This mapping identified sections of the route which currently are at specific risk from surface water flooding. The risk classification assigned at each location is dependent on which FMfSW the receptor is located within.

2.6.13 The Proposed Scheme has the potential to interrupt surface water flow which would require mitigation to prevent an increase in flood risk. In addition, other design elements such as landscaping will alter the permeability of the ground and hence modify sections of the surface water catchments. The assessment involved determining the land drainage catchments, surface water run-off from these catchments and the capacity of Sustainable Drainage Systems (SuDS) and culverts.

2.6.14 Land drainage catchments were identified using topographic data (primarily 5m contours, or 1m contours on small or unclear catchments). The assumption was made that linear features such as roads and railways do not act as a cut off for overland flow.

2.6.15 The calculation of greenfield run-off rates from existing catchments was undertaken using the online SuDS tool[14]. A growth factor of 30% was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during this event with an allowance for climate change. A factor of 62% (based on calculations using the Flood Studies Supplementary Report 14[15]) was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during the 1 in 1000 (0.1%) annual probability event.

2.6.16 Run-off from modified sections of the catchment as a result of the Proposed Scheme (e.g. landscape areas) which alter the permeability was determined using the Institute of Hydrology[16] methodology with a value of 0.5 for the soil parameter and a safety factor of 1.2.

2.6.17 Storage volumes were calculated using the online SuDS tool assuming that landscape areas will be impermeable. The storage volumes required were taken to be the sum of the attenuation and long term storage as a conservative approach.

2.6.18 The calculations for the proposed drainage design have been completed in line with the requirements in Volume 1, Section 9.

Groundwater flood risk

2.6.19 Groundwater bodies and aquifers present within a 1km buffer of the route have been identified and named on available web-based mapping data for the purposes of the Proposed Scheme.

[14] HR Wallingford (2013), UK Sustainable Drainage Guidance and Tool. The Greenfield run-off estimation for sites tool. http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrun-off.aspx.
[15] Institute of Hydrology (1983), *The Flood Studies Supplementary Report Number 14*.
[16] Institute of Hydrology (2004), *Institute of Hydrology, report number 124*. Flood Estimation for Small Catchments.

2.6.20 Field investigations have not yet been undertaken due to limited access to land and the need to integrate investigative requirements from several disciplines.

Sewer systems flood risk

2.6.21 The risk of flooding from the sewer network has also been addressed as part of this assessment. The sewer network data was provided for this assessment by the relevant water company, Severn Trent Water, to determine locations of the route and other design elements which will be located at areas of risk.

Other sources of flood risk

2.6.22 Reservoir flood risk was assessed using the reservoir inundation maps as shown on Volume 5: CFA20 Map Book, Maps WR-01-025, 026 and 027. The purpose was to identify areas along the route that were at risk of flooding if any reservoirs in the vicinity were to fail.

2.6.23 Canals were identified as another source of potential flood risk, and therefore canals that will be crossed by the Proposed Scheme have been identified in the assessment.

3 Design criteria

3.1 Principal design criteria

3.1.1 The Proposed Scheme will provide a safe and reliable high speed rail link which will be compatible with the existing rail network and also HS1.

3.1.2 The railway will only provide a 'passenger' only service. The railway will not provide 'freight' operation.

3.1.3 The design shall seek to ensure that any impacts as a result of its development will be designed out or minimised as far as practicably possible.

3.2 Flood risk design approach statement

3.2.1 The overall project seeks to ensure that there will be no increase in flood risk to any existing receptors as a result of the Proposed Scheme. This will be achieved by ensuring that overall flood storage capacity is maintained including an allowance for climate change.

3.2.2 In line with the NPPF technical guidance, increases in peak rainfall intensity and peak river flow of 20%, as a result of climate change, have been allowed for as per the period 2085 to 2115. This 20% increase has been used for the purposes of assessing flood risk. However, the hydraulic modelling involves sensitivity testing which includes a 20% increase, in addition to the 20% allowance for climate change.

3.2.3 All underbridge and viaduct crossings will be designed to allow the 1 in 100 (1%) annual probability flow with an allowance for climate change to pass underneath. Upstream water levels will not be increased and a minimum of 600mm freeboard will be provided to the bridge soffits above this level which will allow for debris should flooding occur. On main rivers, where possible, a freeboard of 1m has been allowed.

3.2.4 Main river underbridges and viaducts will also accommodate river maintenance requirements and allow for a 5.3m vertical clearance above the floodplain ground level.

3.2.5 Culverts have been designed to convey the 1 in 100 (1%) annual probability flow with an allowance for climate change, with a freeboard of 300mm as a minimum applied for the culvert design. The design has also taken into account submerged inverts and the inclusion of mammal ledges.

3.2.6 River crossings will minimise any requirement for replacement floodplain storage areas.

3.2.7 The proposed rail infrastructure will be protected against inundation in the 1 in 1000 (0.1%) annual probability flood event. This will be achieved through ensuring a freeboard of 1m on the 1 in 1000 (0.1%) annual probability flood level. The railway drainage will be designed to have capacity up to the 1 in 100 (1%) annual probability peak rainfall event. However the design will also ensure that the flood level does not exceed 1m below the track level during the 1 in 1000 (0.1%) annual probability rainfall event.

3.2.8 All drainage will be attenuated in order that peak surface water run-off from the proposed infrastructure is no greater than the existing current day baseline run-off under the 1 in 100 (1%) annual probability peak rainfall event.

3.2.9 All drainage will be designed to ensure that disruption to existing groundwater flood flows will be kept to a minimum, both during and following construction of the permanent works.

3.3 Cross drainage design approach statement

3.3.1 The drainage design will ensure that there is no increase in run-off to the receiving watercourse as a result of the Proposed Scheme.

3.3.2 Surface and ground water drainage shall be provided so as to ensure that water levels do not rise above a 1m freeboard below the rail level. The route will be designed to ensure safe operation of trains during a 1 in 1000 (0.1%) annual probability event.

3.3.3 As part of the drainage design an allowance of 30% has been added to design events for climate change.

4 Data sources

4.1.1 Consistent with the requirements of the NPPF, this assessment considers the risk of flooding from rivers, overland flow (surface water), rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The route will lie entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are:

- Ordnance Survey (OS) 1:10,000 mapping;
- topographic survey commissioned for the purposes of the Proposed Scheme (200mm grid resolution LiDAR survey, in digital terrain model and digital surface model format);
- Environment Agency Flood Zone mapping and historic flood mapping;
- the Environment Agency website for reservoir inundation mapping;
- the Stratford-on-Avon SFRA[9];
- the Warwickshire SFRA[17];
- Warwickshire PFRA[10];
- Environment Agency national surface water flood mapping datasets specifically the Midlands FMfSW; and
- Severn Trent Water asset mapping.

4.1.4 A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding, or a risk of flooding to the line, further investigation is undertaken, specifically hydraulic modelling for the areas at risk from river flooding.

[17] Warwickshire County Council (2008), *Warwickshire Strategic Flood Risk Assessment*.

5 The Proposed Scheme

5.1 Permanent works

5.1.1 The general design of the Proposed Scheme is described in Volume 2, Section 2.2. The following section describes the main features of the Proposed Scheme in this study area, which are specifically relevant for this FRA.

Overview

5.1.2 The Proposed Scheme through the Ladbroke and Southam area is approximately 13km in length and will commence to the east of Wormleighton. The route then proceeds north-westwards, leaving CFA16 as it crosses a small watercourse to the south of the Grand Union Canal.

East of Wormleighton to north of Footpath SM101 green overbridge

5.1.3 The approximate length of this section will be 1.3km. The Proposed Scheme will enter the area on a cutting north of the Banbury Road realignment (Volume 2: CFA16 Map Book, Map CT-06-079b, E6). Key features of this section, which have been assessed in this FRA, will include a cutting 1.3km long with a depth of up to 16m. The cutting extends back into the Greatworth to Lower Boddington area (CFA15) and is a total of 2.4km long.

North of Footpath SM101 green overbridge to Lower Radbourne Farm

5.1.4 The route in this section will be approximately 3km long (Volume 2: CFA16 Map Book, Map CT-06-080, H3 to Map CT-06-082, H7). The key features of this section of the route, which have been assessed in this FRA, will include:

- a viaduct crossing the Oxford Canal;
- viaducts over two watercourses approximately 90m and 50m long at Lower Radbourne;
- three balancing ponds constructed on the west side of the railway, adjacent to the Oxford Canal, the Lower Radbourne south viaduct and Lower Radbourne north viaduct, and a further pond on the east side of the route close to Chapel Bank Cottage;
- realignment of Bridleway SM116 around a railway balancing pond and beneath the viaduct over the Oxford Canal to reconnect with the existing alignment east of the route; and
- two flood storage areas east of the route for the watercourses crossed by the Lower Radbourne viaducts to offset any impacts from the Proposed Scheme.

Lower Radbourne Farm to south of Ladbroke Grove Farm

5.1.5 The route in this section will be approximately 1.1km long (Volume 2: CFA16 Map Book, Map CT-06-082, H7 to A6). The key features of this section of the route, which have been assessed in this FRA, will include a 1.1km-long cutting of depth of approximately 8.5m.

South of Ladbroke Grove Farm to the A423 Banbury Road

5.1.6 The route in this section will be approximately 2.9km long (Volume 2: CFA16 Map Book, Map CT-06-082, A6 to Map CT-06-084, D6). Key features of this section of the route, which have been assessed in this FRA, will include:

- a 2.3km-long cutting with a depth of approximately 29m as it passes through Windmill Hill;
- Ladbroke culvert to provide a crossing for an unnamed stream; and
- two railway balancing ponds constructed to the west of the route in the vicinity of two highway balancing ponds along the A423 Banbury Road realignment.

A423 Banbury Road to the River Itchen

5.1.7 The route in this section will be approximately 1.8km long (Volume 2: CFA16 Map Book, Map CT-06-084, D6 to Map CT-06-084, B5). Key features of this section of the route, which have been assessed in this FRA, will include:

- a 1.1km cutting with a depth of approximately 10.5m;
- a culvert at Southam to provide a crossing for a dry valley;
- a balancing pond constructed on the east side of the railway south of the River Itchen;
- a balancing pond on the west side of the B4451 Kineton Road and a balancing pond on the east side of the route near the River Itchen; and
- an additional flood storage area west of the route and south of the River Itchen to offset any impacts from the Proposed Scheme.

River Itchen to Grand Union Canal

5.1.8 The route in this section will be approximately 3.2km long (Volume 2: CFA16 Map Book, Map CT-06-084, B5 and Map CT-06-084, B7). Key features of this section of the route, which have been assessed in this FRA, will include:

- a 90m long viaduct over the River Itchen;
- a drainage pond on the east side of the route just north of the River Itchen;
- Long Itchington Wood green tunnel and Long Itchington Wood tunnel, with a combined length of approximately 1.8km;
- a 350m long cutting with a depth at the north portal of approximately 11m;
- provision of a balancing pond with access from Welsh Road to the north via the tunnel portal access road;
- additional flood storage areas south of the River Itchen on the west side of the route and to south of the Grand Union Canal on the east side of the route to offset any impacts from the Proposed Scheme; and
- local realignment of a minor watercourse around the south approach embankment to Longhole Viaduct in the Offchurch and Cubbington area

(CFA17).

5.1.9 The route will leave the Ladbroke and Southam area to the north on embankment at the minor watercourse to the south of the Grand Union Canal.

5.2 Temporary works

5.2.1 All contractors will be required to comply with the environmental management regime for the Proposed Scheme, which will include:

- Code of Construction Practice (CoCP); and
- Local Environmental Management Plans (LEMP).

5.2.2 The key requirements of the draft CoCP in relation to flood risk are:

- making appropriate use of the Environment Agency's flood warning service;
- preparing site specific flood risk management plans for temporary works at risk of flooding from river, surface water and groundwater sources;
- considering flood risk when planning temporary sites and storing materials;
- obtaining consent, as required, for works affecting a watercourse;
- removing or stopping and sealing of drains and sewers taken out of use;
- not discharging of site run-off to ditches, watercourses, drains or soakaways without agreement of the appropriate authority;
- ensuring hoarding and fencing in areas at risk of flooding will be permeable to floodwater, unless otherwise agreed with the Environment Agency or Local Lead Flood Authority; and
- implementing precautions to be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

5.2.3 The temporary works will include both main and satellite construction compounds. These construction compounds will be utilised for office accommodation, local storage for plant and materials, car parking, material processing facilities and welfare facilities.

5.2.4 Areas adjacent to these construction compounds may be used for temporary storage of topsoil stripped as part of the works.

5.2.5 Temporary worker accommodation will also be required for construction of the Proposed Scheme.

6 Existing flood risk

6.1.1 Through the use of the Environment Agency historical flood maps, one recorded incident of flooding in the vicinity of the route has been identified in this study area. This event caused inundation 600m east of the River Itchen viaduct (Volume 5: Map Book, Map WR-01-026, B6) and the mapping suggests that this was the result of overtopping from the River Itchen. The date of this flooding event has not been provided.

6.1.2 The historic flood maps are not readily available as part of the Stratford-on-Avon SFRA[9], however this SFRA outlines several large scale flood events from 1947 to 2007. Given that detailed locations of these flood events are not provided in the Stratford-on-Avon SFRA, and that the mapping is not freely available, it is not possible to determine whether these events have occurred at the location of the Proposed Scheme.

6.1.3 Historic maps in the Warwickshire SFRA[17] (which encompasses various districts and boroughs including Stratford-on-Avon) have been utilised for this assessment. The sources of historical flooding mapped in the Warwickshire SFRA are river, surface water, canal breaching, artificial drainage and unknown. As shown on this mapping, there are no known areas of historical flooding along the line of the route. Flooding incidents in this study area have been recorded at Ufton and Fenny Compton (both unknown source of flooding) and canal flooding has been recorded at Long Itchington, although these do not fall within the 1km land required for the Proposed Scheme. As reported in the Warwickshire SFRA, the incidents of canal flooding at Long Itchington were the result of embankment failure and river scour (the most recent event was in 1977). Subsequently, the river has been re-aligned and the canal embankment rebuilt and no further flood events have been recorded, and hence future failure at this location is considered low. The Warwickshire SFRA indicates that there have been no other historic incidents of flooding within 1km of the route, such as in Southam.

6.1.4 The Warwickshire PFRA[10] has also been used to identify potential locations of flooding in the vicinity of the route, There appears to be a number of recorded incidents of flooding, classed as exceptional (greater than every five years), within 1km of the route in the areas around Ladbroke and Southam. However these events are not identified to be at the location of the Proposed Scheme.

6.2 River flooding

6.2.1 River flood risk is the risk of flooding posed by rivers and streams. The risk in CFA16 is from the River Itchen and its tributaries and a tributary of the River Leam. The areas at risk of flooding from this source are shown in Volume 5: Map Book – Water resources, Maps WR-05 and WR-06.

6.2.2 The assessment of baseline (current) flood risk involved identifying watercourse crossings and the associated risk through the use of the Environment Agency Flood Zones. The results of this assessment are provided in Table 2. The watercourse identifier references have been taken from Volume 5: Map Book – Water resources, Maps WR-01-025 to 027.

Table 2: Ladbroke and Southam river flood risk

Watercourse identifier and map reference	Crossing name	Watercourse	1 in 100 (1%) + climate change flow	Risk level	Receptor vulnerability
SWC-CFA16-002 Volume 5: Map WR-01-025, D5	Lower Radbourne south viaduct	Ordinary watercourse (tributary of the River Itchen)	10.05 m^3/s	Very high	Less vulnerable
SWC-CFA16-003 Volume 5: Map WR-01-025, C5	Lower Radbourne north viaduct	Ordinary watercourse (tributary of the River Itchen)	8.92 m^3/s	Very high	Less vulnerable
SWC-CFA16-004 Volume 5: Map WR-01-025, B4	Ladbroke culvert	Ordinary watercourse (tributary of the River Itchen)	1.73 m^3/s	Very high	Less vulnerable
The area at risk is located to the west of the Banbury Road realignment. Volume 5: Map WR-01-026, D6	-	Flood Zone associated with a tributary of the River Itchen. The route does not cross a watercourse at this location.	-	High	Less vulnerable
SWC-CFA16-005 Volume 5: Map WR-01-026, B6	River Itchen viaduct	Ordinary watercourse (River Itchen)	61.78 m^3/s	Very high	Less vulnerable
Volume 5: Map WR-01-026, B6	Long Itchington Wood tunnel	Ordinary watercourse (tributary of the River Itchen)	Not modelled	Low	Less vulnerable
SWC-CFA16-006 Volume 5: Map WR-01-027, E5	Longhole viaduct	Ordinary watercourse (tributary of the River Leam)	4.70 m^3/s	Very high	Less vulnerable

6.2.3 The Environment Agency Flood Zone mapping indicates three main areas at risk from flooding:

- the River Itchen tributaries at the location of the Lower Radbourne north and south viaducts (Volume 5: Map WR-01-025, C5 and D5);
- the River Itchen viaduct (Volume 5Map WR-01-026, B6); and
- a tributary of the River Itchen which is not crossed by the route (Volume 5: Map WR-01-026, D6).

6.2.4 The crossing locations are identified to fall within Flood Zone 3. However, given that the route crosses the watercourse, they will also be located within Flood Zone 3b (very high risk). In the area to the west of the Banbury Road realignment (as listed in Table 2), a section of the route slightly encroaches into Flood Zone 3, but without crossing a watercourse. This area has been classed as at a high risk in line with the risk category matrix in Table 1.

6.2.5 The Environment Agency flood mapping covers watercourses with catchments greater than 0.5km^2, and hence small catchments are often not represented.

6.2.6 There are no Environment Agency Flood Zones associated with two of the River Itchen tributaries which are crossed by the route, specifically at the Ladbroke culvert

(Volume 5: Map WR-01-025, B4) and Long Itchington Wood tunnel (Volume 5: Map WR-01-026, B6). In addition, the Environment Agency Flood Zone mapping in the vicinity of the Longhole viaduct (Volume 5: Map WR-01-027, E5) is misaligned and shows the flood zone associated with the canal rather than the watercourse.

6.2.7 Hydraulic modelling was carried out to provide a more accurate representation of river flood risk along the route, specifically at locations where the route will cross a watercourse. The modelling provided flood extents for the 1 in 100 (1%) annual probability event with a 20% allowance for climate change and for the 1 in 20 (5%) annual probability event. Flood levels were also determined for the 1 in 1000 (0.1%) annual probability event to ensure that the proposed track will not be at risk during this event. The flood extents and levels as determined through hydraulic modelling are further detailed in the river modelling report (Volume 5: WR-004-009).

6.2.8 The hydraulic modelling redefines the Flood Zones at the location of the proposed Longhole viaduct. Therefore the watercourse crossed by this structure is identified to be within Flood Zone 3b and hence classed as at a very high risk in line with Table 1.

6.2.9 Similarly, the Environment Agency Flood Zone mapping indicates that the Ladbroke culvert is located within Flood Zone 1. However, following hydraulic modelling completed for this assessment it is redefined as Flood Zone 3b. Therefore the risk classification given to this location is very high.

6.2.10 The watercourse in proximity to the Long Itchington Wood and the Long Itchington Wood tunnel is located in Flood Zone 1. Given that the route would be within a tunnel at this location, there will be no impact on river flood risk, the watercourse has not been modelled and the associated risk is low.

6.2.11 The vulnerability classification as shown in Table 2has been taken from the NPPF and relates to the vulnerability of existing development in areas currently at risk from river flooding. The vulnerability classification given to the watercourse crossings in this study area is less vulnerable because there are no properties within the vicinity of any of the crossings and the primary land use is agricultural. This is based on Leamington Road (A425), the road downstream of the River Itchen viaduct, being categorised as less vulnerable, i.e. it is not essential infrastructure acting as a mass evacuation route.

6.2.12 The other locations along the route not identified in Table 2 are considered to be at either a low risk or no risk of river flooding.

6.3 Surface water / overland flow

6.3.1 This section is an examination of the existing flood risk posed by rainfall falling on the ground surface, referred to as surface water flooding. It is examined in terms of the water flowing over the ground surface that has not entered a natural drainage channel or artificial drainage system.

6.3.2 The areas at risk from surface water flooding are shown on Volume 5: Maps WR-01-025 and 027. Table 3 details the risk to the development from this source of flooding.

Table 3: Ladbroke and Southam sources of surface water flooding

Description of surface water flooding location	Description of possible influence to the Proposed Scheme	Risk
In the vicinity of the diverted footpath SM101 Volume 5: Map WR-01-025, G6	The route will cross areas susceptible to surface water flooding at two separate points. Neither of these areas at risk is associated with watercourses. The areas identified are categorised as being at a low or medium risk.	Medium
In the vicinity of the diverted footpath SM116a and its underbridge Volume 5: Map WR-01-025, F6	The route will cross areas susceptible to surface water flooding at two separate points. Neither of these areas at risk is associated with watercourses. The areas identified are categorised as being at a low or medium risk.	Medium
To the north of the Oxford Canal viaduct Volume 5: Map WR-01-025, E6	The route will cross an area susceptible to surface water flooding which is broadly associated with a watercourse. This area at risk is categorised as being at low and medium risk.	Medium
At the Lower Radbourne south and north viaducts Volume 5: Map WR-01-025, C5 and D5	The route will cross two areas susceptible to surface water flooding which area associated with two watercourses at this location (SWC-CFA16-002 and -003). The areas at risk are predominately categorised as being at low and medium risk, however isolated areas upstream and downstream from these crossings are categorised as being at a high risk.	High
Chapel Bank Cottage Volume 5: Map WR-01-025, D4	To the east and west of the Proposed Scheme at this location, there are two surface water flow paths which discharge to the ordinary watercourse (SWC-CFA16-003) which will be crossed by the Lower Radbourne north viaduct. The route will cross one of these surface water flow paths to the north of Chapel Bank Cottage. This area at risk is predominately categorised as being at low and medium risk, but with isolated areas of high risk.	High
In the vicinity of Ladbroke culvert Volume 5: Map WR-01-025, B4	The route will cross and be located in close proximity to three surface water flow paths, one of which is associated with the watercourse at this location (SWC-CFA16-004). The area at risk is predominately categorised as being at low and medium risk, but with isolated areas of high risk.	High
To the east and west of Banbury Road Volume 5: Map WR-01-026, E5 and E6	The route will cross a surface water flow path categorised as being at a low and medium risk in the southern section of this area. To the north of Banbury Road the route crosses an area categorised as being at a low, medium and high risk of surface water flooding.	High
In the vicinity of River Itchen viaduct Volume 5: Map WR-01-026, C6 and B6	The route will cross an area susceptible to surface water flooding which is associated with the River Itchen (SWC-CFA16-005). This area at risk is categorised as being at a low, medium and high risk of surface water flooding.	High
To the north of the Long Itchington Wood porous portal to Long Itchington Wood Volume 5: Map WR-01-026, B6	Along this section of the Proposed Scheme the route will cross several small isolated areas at risk from surface water flooding. These areas are primarily categorised as being at low and medium risk, although one area is categorised as being at high risk.	High
Wood Farm Cottage Volume 5: Map WR-01-027, E6	The route will cross a surface water flow path which is categorised as being at a low and medium risk of surface water flooding. This flow path is not associated with a watercourse.	Medium
Longhole viaduct Volume 5: Map WR-01-027, E5	The route will cross and will be located in close proximity to areas at risk from surface water flooding which are categorised as being at a low and medium risk of surface water flooding.	Medium

6.3.3 There are 11 locations along the route in this study area which have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. At the majority of these locations the risk of surface water flooding ranges from low to high, however as a conservative approach the highest level of risk has been assigned. Therefore at six locations the risk is considered to be high and at five locations the risk is considered to be medium.

6.3.4 In line with the risk category matrix provided in Table 1, and the data available for this FRA, all other locations along the route within this study area are classed to be at no risk from surface water flooding.

6.4 Groundwater

6.4.1 Groundwater flood risk has been qualitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions at the location of the Proposed Scheme. The assessment of the current groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth of groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

6.4.2 Both the Stratford-on-Avon SFRA and the Warwickshire SFRA indicate that there are no known major issues from groundwater flooding. The overall risk of groundwater flooding within this study area ranges from high (around the River Itchen, to the north of the Oxford Canal and south of Ladbroke) to low (from Southam to Bascote Heath).

6.5 Sewer systems

6.5.1 Sewer infrastructure is a potential source of flood risk in the event of a failure. Due to the nature of the closed sewer system, sewer flooding will only be caused if there is a blockage or a leak or if there is a rainfall event greater than the design capacity of the network.

6.5.2 The risk to the route from the sewer network has been determined based on the location of development in relation to the network and the proximity and potential flow paths from inspection covers. Flow paths have been assessed through the use of LiDAR and OS mapping. A summary of this assessment is included in Table 4.

Table 4: Ladbroke and Southam sources of sewer network flooding

Location	Supplier	Comment	Risk
Volume 2: CFA16 Map Book, Map CT-06-086, G5	Severn Trent Water	The sewer network is crossed by the Proposed Scheme, but no flow paths or surcharge points within 20m of the site.	Low
Volume 2: CFA16 Map Book, Map CT-06-086, C6	Severn Trent Water	The sewer network and an inspection cover will be crossed by the route. However at this location the proposed track is in a tunnel and hence would not be at risk as a result of surcharging at this location.	No risk

6.5.3 The route crosses the sewer network at two locations in this study area. At one of these two locations the route will cross an inspection cover and hence surcharge point. However at this location the route will go into a tunnel and therefore there will be no potential flow path to the Proposed Scheme.

6.6 Artificial sources

6.6.1 Artificial sources of flood risk describe a mechanism whereby flooding would be the result of failure of infrastructure that impounds water such as a canal or reservoir.

6.6.2 There are two canals within this study area that poses a risk to the Proposed Scheme. These are the Oxford Canal, which will be crossed by the proposed Oxford Canal viaduct, and the Grand Union Canal, which will be crossed by the Longhole viaduct.

6.6.3 Topographic data (specifically LiDAR) indicates that the Oxford Canal, at the location of the crossing, is raised above surrounding ground level to the north. If structural breaching occurs, flooding is likely in the land to the north of the canal which is classed as less vulnerable. Due to the managed nature of water levels within canal systems and based on the risk category matrix (Table 1) it has been determined that the risk of flooding from this source is low.

6.6.4 At the northern extent of this study area the route crosses the Grand Union Canal at the Longhole viaduct. Through the use of LiDAR it is considered that the Grand Union Canal, at the location of the crossing, is not fully raised although embankments are present potentially impounding water during periods of high water levels. Therefore if structural breaching occurs, during periods of high water levels, flooding may occur. However water levels in canals are highly maintained and thus overtopping or failure is considered unlikely. Therefore in line with the risk category matrix in Table 1 it is considered that the flood risk from this source is low.

6.6.5 There is one location along the Proposed Scheme in this study area that would be at risk of flooding as a result of reservoir failure. East of Southam near the Napton Junction of the Grand Union Canal is Napton Reservoir which is situated 7km upstream of the River Itchen viaduct. Should this reservoir fail, flood water would flow in a south westerly direction along the River Stowe and through the village of Offchurch, before reaching the River Itchen and backing up to the Proposed Scheme crossing at the River Itchen viaduct. However the reservoir inundation maps suggest that the area at risk extends to the location of the proposed viaduct and not significantly further upstream. In addition the width of the inundation is less than the width of Flood Zones 2 and 3 at this location.

6.6.6 Due to the strict regulations and high maintenance associated with reservoirs the risk of breaching is considered unlikely. In line with the risk category matrix in Table 1 the risk of flooding from this source is considered to be low.

6.7 Summary

6.7.1 The Proposed Scheme will cross five watercourses and therefore it is concluded that the Proposed Scheme is within areas that are classified as being potentially at a very high risk from river flooding in this study area. The only land uses at risk in this study area (which could be impacted as result of the Proposed Scheme) are classed as less vulnerable.

6.7.2 There are numerous locations along the route which have been identified to be at risk from surface water flooding. The risk to the development at these locations range from low to high.

6.7.3 The SFRA and PFRA do not report any incidence or risk of groundwater flooding and therefore the risk from this source of flooding is considered low.

6.7.4 The route will cross the sewer network at two locations, however because the route will go into a tunnel at these locations, there are no potential flow paths from surcharge points to the Proposed Scheme.

6.7.5 Water levels within canals are continually maintained and hence the chance of overtopping and thus flood risk from this source is considered low. Similarly due to the strict monitoring and maintenance requirements, the risk of reservoir flooding to the development is considered low.

7 Flood risk management measures

7.1 River flood risk

Flood risk to proposed scheme

7.1.1 The Proposed Scheme will be raised above the 1 in 1000 (0.1%) annual probability flood level at floodplain crossings. Therefore, the mitigation measures included in the design have ensured that there are no instances where the Proposed Scheme would be at significant risk of river flooding, and consequently no specific mitigation is required.

Impact of proposed scheme

7.1.2 At all floodplain crossings, replacement floodplain storage would be provided upstream of the Proposed Scheme for losses in floodplain storage, including viaduct piers, embankments and all associated development.

Lower Radbourne south viaduct

7.1.3 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 68mm, extending to a maximum distance of 157m upstream of the Lower Radbourne south viaduct during the 1 in 100 (1%) annual probability event with an allowance for climate change. This change in flood level causes a moderate impact which will be reduced through the incorporation of replacement floodplain storage.

Other watercourse crossings

7.1.4 The hydraulic modelling for the other four watercourse crossings in this study has shown that the Proposed Scheme will have a minor or negligible impact on river flood risk. Areas of land have been identified as suitable to provide replacement floodplain storage, therefore reducing the impact. Any replacement floodplain storage at the locations of negligible impact is likely to provide betterment.

Mitigation for temporary works

7.1.5 The temporary works have the potential to result in an increased river flood risk and be at risk of flooding from this source. The proposed mitigation and measures to prevent an unacceptable risk of river flooding for the temporary works includes signing up to the Environment Agency flood warning system for the "River Leam and River Itchen – Low-lying land and roads between Grandborough and Leamington, including Long Itchington". Any temporary crossings will be designed to prevent an increased flood risk through ensuring sufficient capacity during the 1 in 100 (1%) annual probability event; an indication of the flows which will be considered are included in Table 2.

7.2 Surface water flood risk

Flood risk to Proposed Scheme

7.2.1 In this study area, the areas categorised as being at a high risk of surface water flooding are generally associated with the watercourses identified in the river flooding sections in this report. At these locations the scheme design will ensure that the track is situated above the 1 in 1000 (0.1%) annual probability event flood level with a 1m

freeboard. Therefore as long as there is no blockage of these structures, a low surface water flood risk to the track is anticipated at these locations.

7.2.2 At the other nine locations where the route potentially crosses surface water flow paths, the track will either be raised on an embankment and/or the drainage system will direct surface water flow away from the Proposed Scheme. Therefore, as long as the collection systems and surface water culverts are designed with sufficient capacity, there should be no backing up, and no expected risk of flooding to the Proposed Scheme.

Impact of Proposed Scheme

7.2.3 Potential increases in peak discharge rates of surface water run-off will be attenuated prior to discharging to the receiving watercourse. Any additional surface water to be discharged will be at a trickle rate to prevent exceeding the current capacity of the receiving watercourse.

7.3 Risk of flooding from groundwater

Flood risk to Proposed Scheme

7.3.1 The Proposed Scheme within this study area overlies multiple aquifers however the works proposed within the study area are not expected to increase groundwater flood risk.

7.3.2 The Proposed Scheme will not cut off groundwater flow within shallow aquifers and therefore significant changes to groundwater flood risk are not expected.

7.3.3 It is recognised that groundwater inflow into cuttings and below ground structures may occur; this will be managed by installing drainage to maintain groundwater levels 1m below the top of the rails.

Impact of the Proposed Scheme

7.3.4 The Proposed Scheme is not anticipated to have an impact on groundwater flooding and therefore no specific management is considered necessary.

7.4 Risk of flooding from sewer systems

7.4.1 There will be a low risk of flooding from sewer systems to the Proposed Scheme, and there are no anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific mitigation would be required.

7.5 Risk of flooding from artificial sources

Flood risk to Proposed Scheme

7.5.1 There are no instances where the Proposed Scheme would be at significant risk of flooding from artificial sources, and consequently no specific mitigation is required.

Impact of the Proposed Scheme

7.5.2 Although the Proposed Scheme is at risk of flooding resulting from the complete failure of Napton Reservoir, the replacement floodplain storage provided to mitigate the potential effects of the River Itchen viaduct would serve to either fully or partially

offset any potential effects of the Proposed Scheme on flooding from this source. Due to the low probability of such flooding occurring, and the likely low significance of any impacts arising from the Proposed Scheme, it is not considered appropriate to provide additional mitigation for this scenario.

8 Post-development flood risk assessment

8.1 River flooding

8.1.1 The key design elements of the route for the Proposed Scheme with potential flood risk considerations have been modelled for this FRA. The river modelling methodology and results specific for each watercourse crossing are included in the river modelling report (Volume 5: WR-004-009). A summary of the results are presented in Table 5. The watercourse identifier references have been taken from Volume 5: Map Book – Water resources, Map WR-01-025 to 027.

Table 5: Ladbroke and Southam river flood risk

Watercourse identifier and map reference	Crossing name	1 in 100 (1%) + climate change flow	Change in flood level 1 in 100 (1%) + climate change	Change in flood level 1 in 1000 (0.1%)	Proposed Scheme 1 in 1000 (0.1%) level	Length of impacted upstream reach[18]
SWC-CFA16-002 Volume 5: Map WR-05-041, F6	Lower Radbourne south viaduct	10.05m^3/s	68mm	81mm	100.47m AOD	157m
SWC-CFA16-003 Volume 5: Map WR-05-041, E6	Lower Radbourne north viaduct	8.92m^3/s	2mm	6mm	99.31m AOD	<20m
SWC-CFA16-004 Volume 5: Map WR-05-042, H6	Ladbroke culvert	1.73m^3/s	-70mm	38mm	99.71m AOD	0m
Not applicable	The area at risk is located to the west of the Banbury Road realignment. Not modelled because the Proposed Scheme does not cross a watercourse at this location.					
SWC-CFA16-005 Volume 5: Map WR-05-043, E7	River Itchen viaduct	61.78m^3/s	20mm	12mm	75.65m AOD	480m
Not applicable	Long Itchington Wood tunnel	Not modelled as Proposed Scheme will pass beneath the watercourse in the tunnel				
SWC-CFA16-006 Volume 5: Map WR-05-044a, E6	Longhole viaduct	4.70m^3/s	39mm	134mm	64.60m AOD	90m

8.1.2 The hydraulic modelling completed for this study area shows that at two of the five watercourses identified in Table 5 (SWC-CFA16-003) the Proposed Scheme would have a negligible impact on flood levels during the 1 in 100 (1%) and the 1 in 1000 (0.1%) annual probability flood events.

8.1.3 At the location of the Lower Radbourne south viaduct the hydraulic modelling has indicated that without mitigation the Proposed Scheme will result in a 68mm flood

[18] Length of reach upstream of the Proposed Scheme along which flood levels during the 1 in 100 (1%) annual probability+ CC are greater than 10mm.

level change during the 1 in 100 annual probability (1%) with an allowance for climate change event, this change in level is classed as moderate and would impact on less vulnerable development. An area of land has been identified that is suitable to provide replacement floodplain storage, therefore reducing the impact. The replacement storage possible within this area is greater than the volume lost due to the Proposed Scheme and hence there is potential that mitigation would reduce the change in flood level to a negligible impact.

8.1.4 The hydraulic modelling at the River Itchen viaduct and the Longhole viaduct indicates that at these locations the Proposed Scheme will have a minor impact on flood levels during the 1 in 100 annual probability (1%) with an allowance for climate change event. However, areas of land have been identified that are suitable to provide replacement floodplain storage, therefore reducing the impact.

8.1.5 An analysis of the topography at the River Itchen and Longhole viaducts, where less vulnerable development would be at risk, indicates that replacement floodplain storage could be provided on a volume for volume basis. The potential locations identified are on the opposite bank to the proposed ecological mitigation (although this could be combined with the ecological mitigation if possible) at the River Itchen viaduct; and on the left bank next to the balancing pond at the Longhole viaduct.

8.1.6 The replacement storage possible within these areas is greater than the volume lost due to the Proposed Scheme and hence it is expected that the mitigation would reduce the change in flood level to a negligible impact.

8.1.7 The minor watercourse at the location of the Long Itchington Wood has not been modelled. This is because the Proposed Scheme is within a bored tunnel and hence there would be no impact on this watercourse in relation to flood risk.

8.1.8 In the area to the west of the Banbury Road realignment, the embankment toe of the Proposed Scheme encroaches slightly into the area at risk of flooding shown on the Environment Agency flood mapping (Flood Zone 3). Modelling and hence refined flood extents were not created because the Proposed Scheme does not cross this watercourse and the encroachment into the area at risk of flooding is small. In this area the land use is categorised as less vulnerable, and any change in flood level will be minor, owing to only slightly encroachment of embankment toe into the area at risk of flooding. Therefore the impact of the Proposed Scheme at this location is considered to be negligible.

8.1.9 Watercourses pose a river flood risk to the other design elements in this study area. The areas at risk from river flooding are shown on Volume 5: Maps WR-05-040 to 044a and WR-06-040 to 044a and are based on the hydraulic modelling results rather than Environment Agency Flood Zone mapping. The river flood risks to these works are included in Table 6.

Table 6: River flood risks to the other design elements

Works at risk	Watercourse identifier and map reference	Location description	Description of the works and flood risk	Risk
Earthworks Landscaping Other	SWC-CFA16-002 Volume 5: Map WR-05-041, F6	Lower Radbourne south viaduct	Proposed landscaping, earthworks and maintenance access points will be located in areas adjacent to this watercourse and within areas identified to be at risk during then 1 in 20 (5%) annual probability event. Utility works are also required at this location.	Very high
Earthworks Landscaping Other	SWC-CFA16-003 Volume 5: Map WR-05-041, E6	Lower Radbourne north viaduct	Proposed landscaping, earthworks and an access track to a proposed balancing pond will be located in areas adjacent to this watercourse and encroach into areas identified to be at risk during then 1 in 20 (5%) annual probability event. Utility works are also required at this location.	Very high
Earthworks Landscaping	SWC-CFA16-004 Volume 5: Map WR-05-042, H6	Ladbroke culvert	Proposed landscaping and earthworks will be located in areas which cross the watercourse at this location.	Very high
Earthworks Landscaping	SWC-CFA16-005 Volume 5: Map WR-05-043, E7	River Itchen viaduct	Proposed earthworks will be located in areas categorised as being at high risk of flooding from this watercourse, and landscaping is proposed in areas classed as being at a very high risk. Utility works are also required at this location.	Very high
Landscaping	SWC-CFA16-006 Volume 5: Map WR-05-044a, E6	Longhole viaduct	Proposed landscaping works will encroach into the areas at risk from river flooding.	High

8.1.10 There are proposed improvements to an access track at the location of the Lower Radbourne north viaduct. However, these proposed works will not include track widening at this location. Thus if there are any changes to the existing culvert at this location, as long as these are like for like, then the Proposed Scheme will have a negligible impact on flood risk.

8.1.11 Additional road culverts are proposed in this study area, however these culverts are required for the surface water drainage system which forms part of the Proposed Works, rather than for existing watercourses. The capacity requirements for these culverts are addressed as part of the drainage design.

8.1.12 Temporary works as required for the construction phase are also located in areas at risk from river flooding. The areas at risk from river flooding are shown on Volume 5: Maps WR-05-040 to -044a and WR-06-040 to -044a and are based on the hydraulic modelling results rather than Environment Agency Flood Zone mapping. The temporary works at risk are listed in Table 7.

Table 7: River flood risk to temporary works

Watercourse identifier and map reference	Receptor	Comment	Risk
SWC-CFA16-002 Volume 5: Map WR-05-041, F6	Ordinary watercourse (tributary of the River Itchen).	Temporary fencing, a temporary plant crossing and a new track/haul road will be located in the areas identified to be at risk during then 1 in 20 (5%) annual probability event.	Very high

Watercourse identifier and map reference	Receptor	Comment	Risk
SWC-CFA16-003 Volume 5: Map WR-05-041, E6	Ordinary watercourse (tributary of the River Itchen).	Temporary fencing, a temporary plant crossing and a new track/haul road will be located in the areas identified to be at risk during then 1 in 20 (5%) annual probability event.	Very high
SWC-CFA16-004 Volume 5: Map WR-05-042, H6	Ordinary watercourse (tributary of the River Itchen).	A temporary plant crossing and a new track/haul road will be located in the areas which cross the watercourse.	Very high
SWC-CFA16-005 Volume 5: Map WR-05-043, E7	Main river (River Itchen).	A temporary plant crossing and a new track/haul road will be located in the areas identified to be at risk during then 1 in 20 (5%) annual probability event.	Very high
CFA16-SW-006 Map WR-05-044a, E6	Ordinary watercourse (tributary of the River Leam).	The only temporary works that will be located in this area at risk are the pedestrian and light vehicle access between the banks via an existing bridge and the proposed location of temporary construction fencing. These works are identified in the area at risk during the 1 in 20 (5%) annual probability event.	Very high

8.1.13 There are five locations of temporary works that are located in areas at risk from river flooding. The areas at risk have been identified through the hydraulic modelling completed for this assessment.

8.1.14 Hydraulic modelling is not considered necessary for the temporary works because the works will be constructed in line with the CoCP and thus the design will consider river flood risk. Therefore temporary works will not result in an increased flood risk to any existing receptors.

8.1.15 The hoarding and fencing around a site for security purposes has the potential to alter flow paths and thus impact on flood risk at the three locations identified in Table 7. However, the CoCP states that hoarding and fencing in areas at risk of flooding will be permeable to floodwater, (as outlined in Section 3 of this report), unless otherwise discussed with the Environment Agency or Local Lead Flood Authority. This will ensure that the floodplain continues to function effectively for storage and conveyance of floodwater.

8.1.16 The temporary works other than those outlined in Table 7 are considered to be at a low risk of river flooding.

8.2 Surface water / overland flow

8.2.1 The proposed track will result in increased run-off rates due to a reduction in infiltration capacity. Therefore the entire length of the track may be at risk from this source and could increase risk elsewhere.

8.2.2 In addition the track drainage has the potential to increase flood risk in receiving watercourses if not attenuated. In this study area there are 11 proposed balancing ponds, these are located as follows:

- to the south of the Oxford Canal viaduct (Volume 2: CFA16 Map Book, Map CT-06-080, B5);

- to the south of the Lower Radbourne south viaduct (Volume 2: CFA16 Map Book, Map CT-06-081, C6);
- to the north and south of the Lower Radbourne south viaduct (Volume 2: CFA16 Map Book, Map CT-06-081, A5 and CT-06-082, H8);
- four in the vicinity of the Banbury Road realignment (Volume 2: CFA16 Map Book, Map CT-06-084);
- in the vicinity of the Kineton Road realignment(Volume 2: CFA16 Map Book, Map CT-06-085, H7);
- to the north and south of the River Itchen viaduct (Volume 2: CFA16 Map Book, Map CT-06-085, C5 and B5); and
- to the south of the Longhole viaduct (Volume 2: CFA16 Map Book, Map CT-06-087, C6).

8.2.3 The outfall from these balancing ponds will be attenuated as described in Volume 1, Section 9 to ensure that run-off rates are not increased above existing levels to prevent an increase in risk.

8.2.4 The route has the potential to interrupt surface water movement, which could result in an increase in surface water flood risk. The Environment Agency FMfSW indicates that the Proposed Scheme will interrupt nine overland flow paths in this study area.

8.2.5 The Proposed Scheme crosses the upstream reaches of four minor overland flow paths to the south of the Oxford Canal viaduct. At this location, any potential interruption of surface water flow will be collected in the proposed drainage channels and diverted under the route at the location of the Oxford Canal culvert where it will be subsequently discharged into the canal. Therefore the interruption of overland flow, as a result of the Proposed Scheme at this location, will not significantly impact on surface water flood risk elsewhere.

8.2.6 An overland flow path is crossed by the route and then flows in a southerly direction, to the west of Chapel Bank Cottage, prior to discharging into the watercourse at this location (Volume 5: Map WR-01-025, C5, SWC-CFA16-003). In the vicinity of this surface water flow path, the Proposed Scheme includes drainage channels on both sides of the route. Therefore any surface water which flows towards the Proposed Scheme will enter these drainage channels, where it will be directed southwards towards the watercourse at this location. The Proposed Scheme will cause a slight alteration to overland flow paths; however, the surface water will ultimately be discharged into the receiving watercourse at a similar location as present.

8.2.7 A surface water flow path has the potential to be interrupted by the Windmill Lane diversion and the route in the area to the west of Lady Hill. However, surface water flowing towards the Proposed Scheme at this location will be collected in the proposed drainage associated with the Windmill Lane diversion and then directed via drainage channels and a culvert to the watercourse at Ladbroke culvert.

8.2.8 Two surface water flows path exists in the vicinity of the Banbury Road diversion, although similarly to the interrupted flows paths discussed above, any surface water flowing towards the Proposed Scheme will be collected in the proposed drainage

channels. The water from these surface water paths will be directed to culvert 124 (Volume 2: CFA16 Map Book, Map CT-06-084, C6) where it will be diverted under the route and discharged into the same watercourse as to where it currently discharges.

8.2.9 At the northern extent of this study area, the Proposed Scheme will interrupt a surface water flow path, which currently discharges into a tributary of the River Leam upstream of the Longhole viaduct. The proposed drainage channels will divert this flow along the western boundary of the Proposed Scheme and into the same watercourse downstream of the Longhole viaduct.

8.2.10 The potential impact of the Proposed Scheme on surface water movement, not identified as above, will be incorporated within the scheme design. Therefore the works will have no impact on surface water flood risk.

8.2.11 There are other design elements of the Proposed Scheme which will be at risk from surface water flooding. The surface flood risks to the other design elements, as identified from the Environment Agency FMfSW are included in Table 8.

Table 8: Surface water flood risks to other design elements of the Proposed Scheme

Works at risk	Location description	Description of possible influence to the Proposed Scheme	Risk
Earthworks Landscaping	To the south of the Oxford Canal viaduct Volume 5: Map WR-01-025, F6	As outlined earlier in this section the Proposed Scheme will cross the upstream reaches of four minor surface water flow paths at this location. The works that would be at risk are landscaping and earthworks, which will be located in areas categorised as being at low and medium risk of surface water flooding.	Medium
Earthworks Landscaping	To the north of the Oxford Canal viaduct Volume 5: Map WR-01-025, E5	Proposed landscaping and earthworks will be located within an area categorised as being predominately at a low risk from surface water flooding, although small isolated areas are categorised as being at a medium risk.	Medium
Earthworks Landscaping Other	Lower Radbourne south viaduct Volume 5: Map WR-01-025, D5	Proposed landscaping, earthworks, utility works and maintenance access points will be located in areas adjacent to this watercourse and within areas identified as being at low and medium risk.	Medium
Earthworks Landscaping Highways Other	Lower Radbourne north viaduct Volume 5: Map WR-01-025, C5	Proposed landscaping, earthworks, a balancing pond and an associated access will be located in areas adjacent to this watercourse and within areas identified as being at low and medium risk. A small part of the proposed access track will be located within an area categorised as being at a high risk of surface water flooding.	High
Earthworks Landscaping Highways	Ladbroke culvert and the area to the north Volume 5: Map WR-01-025, B4	Proposed landscaping, earthworks and an overbridge will be located in areas categorised as being at a low, medium and high risk of surface water flooding. An area susceptible to surface water flooding is located to the north of this watercourse, at the location of proposed landscaping, earthworks and the diversion of Windmill Lane. This area at risk is categorised as being at a low and medium risk of flooding from this source.	High

Works at risk	Location description	Description of possible influence to the Proposed Scheme	Risk
Earthworks Landscaping Highways Other	Areas to the north and south of the Banbury Road diversion. Volume 5: Map WR-01-026, E6	Proposed landscaping, earthworks, the Banbury Road diversion, a balancing pond and utility works will be located in large areas at risk from surface water flooding. These areas at risk are predominately categorised as being at low and medium risk, although areas are also identified as being at high risk.	High
Earthworks Landscaping Highways	River Itchen viaduct Volume 5: Map WR-01-026, C6	Proposed earthworks, landscaping and utility works will be located within areas categorised as being at low and medium risk of surface water flooding. To the north of this crossing, works will be carried out on the A425 which are located in an area categorised as being at a low risk of flooding from this source.	Medium
Earthworks Landscaping Highways	To the south of Longhole viaduct Volume 5: Map WR-01-027, E5	Proposed landscaping, earthworks and an access road will be located in areas as categorised as being at a low and medium risk of surface water flooding.	Medium

8.2.12 There are eight locations where other design elements are located in areas susceptible to surface water flooding. In general these areas range from low to high risk and as a conservative approach the highest level of risk has been assigned. Therefore, three of the eight locations are categorised as being at a high risk and five being at a medium risk of surface water flooding.

8.2.13 The other design elements not listed in Table 8 are considered to be at no risk from surface water flooding in line with the flood risk category matrix.

8.2.14 All other design elements, including those not included in Table 8, have the potential to increase surface water run-off rates through reduced infiltration capacity. The design for the Proposed Scheme includes surface water run-off management (such as drainage channels and balancing ponds) to prevent an increased risk of flooding from this source both on site and in neighbouring areas.

8.2.15 Table 9 details the risk to the temporary design elements from surface water flooding.

Table 9: Sources of surface water flooding to temporary works

Description of surface water flooding location	Description of possible influence on temporary design elements	Risk
To the south of the Oxford Canal viaduct Volume 5: Map WR-01-025, F6	Footpath SM116a underpass compound, a temporary access track/haul road and fencing will be located in areas categorised as being at low and medium risk of surface water flooding.	Medium
To the north of the Oxford Canal viaduct Volume 5: Map WR-01-025, E5	A temporary access track/haul road will be located in areas categorised as being at a low risk of surface water flooding.	Low
Lower Radbourne south viaduct Volume 5: Map WR-01-025, D5	Temporary fencing, a temporary plant crossing and a new track/haul road will be located in areas categorised as being at low and medium risk of surface water flooding.	Medium

Description of surface water flooding location	Description of possible influence on temporary design elements	Risk
Lower Radbourne north viaduct Volume 5: Map WR-01-025, C5	Temporary fencing, a temporary plant crossing and a new track/haul road will be located in areas categorised as being at low, medium and high risk of surface water flooding.	High
Ladbroke culvert and the area to the north Volume 5: Map WR-01-025, B4	A temporary plant crossing and a new track/haul road will be located in the areas which cross the watercourse. These areas are categorised as being at low, medium and high risk of surface water flooding.	High
Areas to the north and south of the Banbury Road diversion. Volume 5: Map WR-01-026, E6	Temporary fencing, a temporary plant crossing, a new track/haul road and a material transfer stockpile area will be located in areas categorised as being at low and medium risk of surface water flooding.	Medium
River Itchen viaduct Volume 5: Map WR-01-026, C6	A temporary plant crossing, a new track/haul road and a material transfer stockpile area will be located in areas categorised as being at low, medium and high risk of surface water flooding.	High
To the south of Longhole viaduct Volume 5: Map WR-01-027, E5	A new track/haul road, a material transfer stockpile area and Sector 2 – Long Itchington Wood compound will be located in areas categorised as being at low and medium risk of surface water flooding.	Medium

8.2.16 There are eight locations where temporary design elements in this study area have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. A conservative approach has been taken in categorising risk as outlined earlier in this section. Therefore, in line with the flood risk category matrix (Table 1) a high risk of surface water flooding has been categorised at three locations, a medium risk at four locations and a low risk at one location.

8.2.17 Satellite construction compounds have the potential to interrupt surface water flow paths. However, there are no satellite construction compounds in this study area that will interrupt surface water flow paths which are identified on the Environment Agency FMfSW.

8.2.18 In line with the risk category matrix provided in Table 1, all other locations for temporary works within this study area are classed to be at no risk from surface water flooding.

8.2.19 The works will be completed in line with the CoCP and hence the design of the temporary works will prevent an unacceptable level of surface water flood risk on site.

8.2.20 Temporary works not identified to be at risk on the FMfSW also have the potential to increase flood risk from this source in neighbouring areas as a result of reduced ground permeability. Therefore, in line with the CoCP, surface water will be managed at all locations of temporary works, including areas not identified to be at risk from surface water in Table 9. This will ensure that the temporary works are at an acceptable level of risk and will not cause an increased risk elsewhere from surface water flooding.

8.3 Groundwater

8.3.1 The Proposed Scheme within this study area overlies multiple aquifers however the works proposed are not expected to increase groundwater flood risk.

8.3.2 The Proposed Scheme will not cut off groundwater flow within shallow aquifers and therefore significant changes to groundwater flood risk are not expected.

8.3.3 It is recognised that groundwater inflow into cuttings and below ground structures may occur; this will be managed by installing drainage to maintain groundwater levels 1m below the top of the rails.

8.4 Sewer systems

8.4.1 The route will cross the sewer network at two locations. At one of these locations the route will be within tunnel and hence is considered to be at no risk of flooding from this source. At the other location there are no flow paths between inspection covers and hence surcharge points to the Proposed Scheme. There the Proposed Scheme (the route, other design elements and temporary works) is at a low risk of flooding from this source.

8.4.2 The works will be completed in line with the CoCP and hence will ensure that the Proposed Scheme and neighbouring areas will not be at an increased flood risk from this source. One such measure outlined in the draft CoCP requires the removal or stopping and sealing of drains and sewers taken out of use. Similarly as outlined in the draft CoCP, precautions will also be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

8.5 Artificial sources

8.5.1 At locations where the route will cross canals or areas at risk of flooding as a result of reservoir failure, there is potential that the Proposed Scheme may either increase risk from this source, or divert flood water causing new areas to be put at risk.

Reservoirs

8.5.2 The Environment Agency reservoir inundation maps indicate that if Napton Reservoir fails, flooding would occur at the location of the River Itchen viaduct (Volume 5: WR-01-027, H5). Should this reservoir fail, flood water would flow in a south westerly direction along the River Stowe and through the village of Offchurch, before reaching the River Itchen and backing up to the Proposed Scheme at the River Itchen viaduct. The reservoir inundation maps indicate that there are no other design elements (with the exception of landscaping) or temporary works of the Proposed Scheme that will located in areas at risk of flooding from this source.

8.5.3 The reservoir inundation extent is narrower than Flood Zones 2 and 3 and hence it is considered that the vertical clearance required for river flooding on this watercourse would be sufficient to prevent significant alteration of flood water flow paths and inundation during reservoir flooding. In addition, Napton Reservoir is situated 7km upstream of the Proposed Scheme and hence the flood water, following a reservoir breach, would be at low velocity when it reaches the Proposed Scheme. Low velocity flood water is likely to cause less damage and pose a lower risk to life.

8.5.4 In line with the risk category matrix (Table 1) the flood risk to all elements of the Proposed Scheme from reservoir failure is considered low.

8.5.5 The daft CoCP outlines that areas at risk of flooding should be considered when planning sites and storing materials. Although the flood risk areas are likely to be

taken from the river flood risk maps, at the location at risk from reservoir inundation in this study area, the reservoir inundation maps are smaller than the areas at risk from river flooding. Therefore it is considered that the temporary works will not significantly alter flood flow paths and hence alter flood risk from this source to other receptors.

8.5.6 There are no other locations within this study area that are at risk of flooding from reservoir failure as shown on the Environment Agency reservoir inundation maps. It is therefore concluded that the Proposed Scheme, including the route, other design elements and temporary works, will be at a low risk of flooding from this source (Table 1) and will not result in an increased risk elsewhere.

Canals

8.5.7 The proposed route involves development that crosses the Oxford Canal at one location and the Grand Union Canal at another location.

8.5.8 The other design elements of the Proposed Scheme in the vicinity of the Oxford Canal are landscaping and earthworks. A temporary bridge will cross the Oxford Canal and temporary access and haul roads are located on both sides of the canal. Oxford Canal compound is located to the north of the Oxford Canal viaduct and Footpath SM116a compound is located to the west of the Oxford Canal at the location of the Footpath SM116a realignment.

8.5.9 The other design elements of the Proposed Scheme in the vicinity of the Grand Union Canal are landscaping and earthworks. A temporary bridge and satellite construction compounds are not located at risk from the Grand Union Canal in this study area.

8.5.10 The canal crossing requires a minimum soffit height for navigational purposes and this soffit would be sufficiently high to prevent any impact on flow. Similarly the works will be undertaken in line with the CoCP and hence will ensure the works are at an acceptable level of risk and that the Proposed Scheme will not cause an increased risk elsewhere.

8.5.11 In line with the risk category matrix in Table 1, the risk to the other design elements and the temporary works is low. These works will be completed in line with the CoCP and hence will not impact on flood risk from this source.

8.6 Summary

8.6.1 The Proposed Scheme will be located in areas at risk from river flooding, including at five watercourse crossings where a very high risk has been assigned. However the hydraulic modelling completed at these five locations identifies that at four of the crossings the impact of the Proposed Scheme is negligible or minor. At the other crossing location in this study area (specifically the Lower Radbourne south viaduct), the impact of the Proposed Scheme is considered to be moderate. Although further hydraulic modelling has shown that the proposed replacement floodplain storage immediately upstream of the crossing will reduce this change to a negligible impact.

8.6.2 All elements of the Proposed Scheme will cross areas susceptible to surface water flooding. In general, at each of the areas the risk ranges from low to high, although as a conservative approach the highest level of risk has been assigned resulting in many

of the areas being categorised as being at a high risk from surface water flooding. However the Proposed Scheme will mitigate surface water run-off to ensure that the works are at an acceptable level of flood risk and do not result in an increased risk elsewhere.

8.6.3 The Proposed Scheme will involve development within an area at a low risk from groundwater flooding. However the design involves measures to ensure that the development is an acceptable level of risk and that the Proposed Scheme does not increase flood risk from this source.

8.6.4 There is a low risk to the Proposed Scheme including the route, other design elements and the temporary works of flooding from the sewer network. However the works will be completed in line with the CoCP and hence will ensure that the Proposed Scheme and neighbouring areas will not be at an increased flood risk from this source.

8.6.5 Water levels within canals are continually maintained and hence the chance of overtopping and thus flood risk from this source is considered low. Similarly due to the strict monitoring and maintenance requirements, the risk of reservoir flooding to the development is considered low. The design ensures that the Proposed Scheme does not result in an increased risk from this source both to the development and elsewhere.

9 Conclusions

9.1.1 The Proposed Scheme, including the route, other design elements and the temporary works, are to be located within areas at risk from flooding from a range of sources. However the temporary works will be designed to and will follow the CoCP such that development will be at an acceptable level of risk and will not cause an increased risk elsewhere. The proposed mitigation as part of the permanent works will also ensure that the Proposed Scheme will be at an acceptable level of flood risk and will not result in an increased risk elsewhere.

9.1.2 The magnitude of impact and significance of effects have been based on the Environmental Impact Assessment (EIA) Scope and Methodology Report (SMR, see Volume 5: Appendix CT-001-000/1). Table 10 shows a summary of the sources of flood risk within this study area and the associated magnitude of impact and significance of effects.

9.1.3 In terms of river flooding, the magnitude of impact in this study area of the Proposed Scheme with the floodplain replacement storage is negligible and significance of effects neutral.

9.1.4 Although there are areas of the Proposed Scheme at no, low, medium and high risk from surface water flooding, overall the risk from this source is categorised as high, as a conservative approach. However the overall magnitude of impact is negligible and the significance is neutral. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 3 of this report and that the temporary and construction works assessed as part of this FRA are in line with the draft CoCP.

9.1.5 The risk on groundwater flooding in the study area is low and there are no likely significant changes to flood risk as a result of the Proposed Scheme.

9.1.6 The risk from water and sewer flooding is low within this study area, and the overall magnitude is negligible with a neutral significance. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 3 of this report and that temporary and construction works assessed as part of this FRA are in line with the draft CoCP.

9.1.7 In this study area artificial sources of flooding (both from reservoir failure and canals) have also been categorised as low, resulting in a low significance of effect.

Table 10: Summary of Flood Risk Receptors showing the overall magnitude of impact and significance of effects

Flood risk receptor	Risk category	Magnitude of impact	Significance of effects
Areas at risk from river flooding	Very High	Negligible	Neutral
Areas at risk from surface water flooding	High	Negligible	Neutral
Areas at risk from groundwater flooding	Low	Negligible	Neutral
Areas at risk from drainage and sewer flooding	Low	Negligible	Neutral
Areas at risk of flooding from artificial sources	Low	Negligible	Neutral

9.2 Residual flood risk to the Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from river sources

Lower Radbourne north and south viaducts

9.2.2 There are two existing hydraulic structures in the vicinity of the proposed Lower Radbourne north and south viaducts. Upstream of these proposed structures there are existing access track crossings and therefore blockage at these structures will not lead to any significant increase in the risk of flooding to the Proposed Scheme. Depending on the constriction on flow caused by the existing access track crossings, any failure of these structures could potentially cause a minor increase in flood levels at the location of the Proposed Scheme.

Ladbroke culvert

9.2.3 There is one existing hydraulic structure in the vicinity of the Ladbroke culvert. This structure is an existing access track crossing, located upstream of the proposed culvert. Depending on the constriction on flow caused by this existing crossing, any failure of the structure could potentially cause a minor increase in flood levels at the location of the Proposed Scheme.

River Itchen viaduct

9.2.4 There is one existing hydraulic structure in the vicinity of the River Itchen viaduct. This is the existing road bridge for the A425 Leamington Road which is located approximately 100m downstream of the Proposed Scheme. There is potential that blockage at this existing road bridge will impact on flood levels at the location of the Proposed Scheme. However, the viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Longhole viaduct

9.2.5 There are two existing hydraulic structures in the vicinity of the Longhole viaduct, the Welsh Road Bridge and the Longhole Bridge. The Welsh Road Bridge is located upstream of the Proposed Scheme and therefore blockage at this structure will not lead to any significant increase in the risk of flooding to the Proposed Scheme. Depending on the constriction on flow caused by the Welsh Road Bridge, any failure of the structure could potentially cause a minor increase in flood levels at the location of the Proposed Scheme.

9.2.6 Longhole Bridge is located immediately downstream of the Proposed Scheme and there is the potential that blockage at this structure would impact on flood levels at the location of the Proposed Scheme. However the viaduct will be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Residual flood risks from surface water sources and minor watercourses

9.2.7 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at dry valley crossings arising from potential blockage of culverts.

Residual flood risks from groundwater

9.2.8 Groundwater levels rise and fall relatively slowly, and therefore any change in the risk of flooding from this source would be the result of below ground intervention. The risk of groundwater flooding already considered in this FRA presents an absolute risk, and there are no significant residual risks arising from this source.

Residual flood risks from the water and sewer network

9.2.9 Blockage of underground water and sewer networks can cause surcharge and associated flooding. At locations where the existing sewer infrastructure will need diverting, any replacement infrastructure would be to at least the same standard as existing. Consequently, no additional residual risk to the Proposed Scheme would be expected as a result of drainage system failure.

Residual flood risks from artificial and surface sources

9.2.10 This assessment considers the potential for total failure of Napton Reservoir, the Oxford Canal and the Grand Union Canal, which is deemed to be the most extreme case of flooding from these sources. Therefore it is considered that there are no further residual risks from artificial sources of flood risk.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 All culverts within the Proposed Scheme will be designed to convey the 1 in 100 year (1% annual probability) flow including an allowance for climate change with a minimum internal headroom of 300mm above the design flood water level (to minimise the risk of blockage). Consequently, there would be negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.3.2 All viaducts within the Proposed Scheme will also be designed so that the 1 in 100 (1%) annual probability flow with an allowance for climate change can pass underneath. As a minimum the design will ensure a 600mm freeboard will be provided to the bridge soffits above this level, and on main rivers where possible, a freeboard of 1m will be allowed. These freeboards will allow for debris and hence prevent a significant increase in residual risk in upstream areas as a result of the Proposed Scheme.

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